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THEORY OF AURORAS OF THE OUTER PLANETS

FINAL TECHNICAL REPORT FOR NASA GRANT NAG8-110

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FINAL TECHNICAL REPORT

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Research under this project has included investigations of the physics of the aurora on three of the four planets visited by Voyager, namely Jupiter, Uranus, and Neptune. At Jupiter, we have focussed on polar IR emissions and their relationship to the UV aurora. At Uranus and Neptune, we have concentrated on understanding the morphology and excitation mechanisms of the UV aurora detected by the Voyager Ultraviolet Spectrometer.

Jupiter. A. J. Dessler and J. Zhan are completing work on a magnetospheric explanation for the Jovian north and south polar IR hot spots (infrared emissions coming from somewhere within the 1b to 1mb level of the atmosphere). The two polar hot spots exhibit different behavior with regard to longitudinal drift in the two hemispheres: the northern polar hot spot (hereafter, NPHS) is fixed in System III longitude while the southern polar hot spot (SPHS) is not [Caldwell et al., 1988]. We have investigated two possible sources of power and reasons for the difference in drift motion of these hot spots. One possibility is that power for the hot spots comes from energetic particle deposition. However, we find that the flux of particles capable of penetrating to the low altitudes required to produce the hot-spot emission is too small to account for the IR power radiated. Also, it is hard to see how particle precipitation could produce the observed differences in drift motion (Voyager measurement of Jovian UV aurora, which is produced mainly by direct particle impact, does not show any significant drift motion of the aurora in either hemisphere). We propose that Joule heating associated with Pederson currents in the lower atmosphere is a more successful hypothesis. (The Pedersen currents are generated by the spinning magnetized ionosphere, which acts as a Faraday Disc Dynamo. The currents close through the Birkeland currents in the magnetotail that cause field lines in the tail to twist.) The altitude of maximum

Pedersen conductivity falls within the range of inferred hot-spot altitudes. We suggest that Joule heating from dissipation of electrical currents in the ionosphere near auroral latitudes may play a fundamental role in producing the north and south polar hot spots. We propose a quantitative perturbation model to account for the localization of the NPHS. The model shows the NPHS is confined by a steep longitudinal magnetic-field gradient to a System III longitude of approximately 180°, in agreement with observations. Using this model, we derive a Joule heating power of about 10^{16} watts, which matches the power requirements for the hot spots. We explain the motion of the SPHS in terms of atmospheric gravity waves, which move the longitudes of both peak ionospheric conductivity and enhanced methane concentration. (The IR is emitted by the v_4 bands of methane.) Because the surface magnetic field in the polar region of the southern hemisphere has less longitudinal variability than that of the northern hemisphere, we find that these atmospheric gravity waves are capable of overcoming the confining force of the smaller magnetic field asymmetries in the southern polar region. We have derived a gravity-wave model for the Jovian atmosphere, and we find the group velocity of the wave can be as high as several km/sec, which matches the drift speed of the SPHS. The current-driven joule heating thus accounts for the primary features of the Jovian polar hot spots: their power output, the fixed location of the NPHS, and the drift speed of the SPHS.

Uranus. We have used Voyager UVS observations to map the Uranian aurora (Herbert and Sandel, 1989). Knowledge of the auroral power and morphology are fundamental to our understanding of magnetospheric processes and the dynamics of the upper atmosphere. Auroral energy influx may be particularly important on the dark side, where solar input has been absent for 20 years. On the sunlit side, knowledge of the auroral emission is needed for proper interpretation of dayglow observations. Because unfavorable observing geometry places the dayside auroral zone near the limb of Uranus, and because the dayside aurora must compete with bright dayglow, we have developed special techniques to quantify it.

We have interpreted the UVS observations of the aurora by a least squares fitting procedure. The surface intensity function was a sum (with coefficients to be determined by the fit) of sky background, solar reflection, and a linear combination of planetary surface emission functions that rotate with the planet. The oblateness of Uranus, the motion of Voyager along its trajectory, the scan platform pointing, and integration over the spatial response function of the UVS slit were all incorporated.

The planetary emissions distribution was modeled by two separate sets of functions: spherical harmonics, and 2D histograms. Each type of fit has its virtues; the spherical harmonics are smoother and more flexible but tend to "ring" and values in one region can affect values in another. The 2D histograms have the advantage that each subregion is completely independent of the others. Thus the data were fit with each type of function. To visually define the auroral emission region, the resulting images displaying the emission functions were co-multiplied so that the 2D histograms could suppress the spurious peaks of the spherical harmonic fit.

The resulting maps of auroral luminosity show good agreement between the measured position of the southern auroral oval and that predicted by Connerney et al. (1987). The observed southern oval may be larger that the prediction. The observed northern oval is longer and considerably wider than either the Connerney et al. Miranda footprint or (especially the auroral oval. If this determination survives more rigorous analysis the higher multipole content of the Goddard Q3 magnetic field model may need revision. The northern oval may be partially filled in. Separate observations near closest approach indicate a slightly higher emission level inside the nominal oval. The morphology determined from the least-square procedure is higher at the same position as well, though lower elsewhere. There appears to be an excess of brightness at the ends of the observed auroral oval. Whether this indicates lower mirror altitudes or greater pitch angle scattering of magnetospheric electrons is presently unknown.

Neptune. Following the tentative identification of aurora on the dark side of Neptune by Broadfoot et al. (1989), we have examined the spatial distribution of these emissions detected by the Voyager UVS (Sandel et al., 1990). The signal, although weak, has two significant features in its distribution in latitude and longitude: (1) a broad peak near longitude 60 W that extends rather uniformly over the range of observed latitudes (55 S to 50 N with respect to the rotational equator); and (2) a brighter but narrower peak near longitude 240 W that is confined to high southern (rotational and magnetic) longitudes. We interpret the first peak as due to excitation of the nightside atmosphere by photoelectrons from the magnetically conjugate, sunlit hemisphere. The required magnetic conjugacy is a strong function of rotational phase, and maximizes at the nearly pole-on configuration that occurs at the appropriate rotational phase to explain the longitude of the intensity peak. Energetic solar photons (>20 eV) incident on Neptune's dayside can power the observed night side emissions if the overall energy-conversion efficiency is about 0.5%. The second peak can plausibly be attributed to a southern aurora; the field geometry would then seem to require a conjugate (and probably brighter) northern aurora that escaped detection northward of the latitude range sampled by the UVS observations. The power for such an aurora could be extracted from Neptune's rotation by the injection of plasma at Triton's orbit at a rate $dm/dt \sim 1$ kg/s. Such a small mass-loading rate is consistent (Dessler and Sandel, 1989) with the observed quiescence of Neptune's magnetosphere.

Broadfoot, A.L. et al., Ultraviolet spectrometer observations of Neptune and Triton, Science 246, 1459, 1989.

Caldwell, J. et al., Infrared polar brightenings on Jupiter IV. Spatial properties of methane emission, Icarus 74, 331-339, 1988.

Connerney, J.E.P., M.H. Acuna, and N.F. Ness, The magnetic field of Uranus, J. Geophys. Res. 92, 15329, 1987.

Herbert, F., and B.R. Sandel, Characteristics of the Uranian aurora, EOS 70, 1174, 1989.

Sandel, B.R., F. Herbert, A.J. Dessler, and T.W. Hill, Aurora on Neptune? submitted to Geophys. Res. Lett., 1990.